Nurse Education Today 125 (2023) 105767

Contents lists available at ScienceDirect

Nurse Education Today

journal homepage: www.elsevier.com/locate/nedt

Examining the impact of virtual reality on clinical decision making – An integrative review

Carley Jans [a,*], Fiona Bogossian [b], Patrea Andersen [c], Tracy Levett-Jones [d]

[a] School of Nursing, University of Wollongong, Faculty of Science, Medicine and Health, Australia
[b] School of Health, University of the Sunshine Coast, 1 Moreton Parade, Petrie QLD, 4502, Australia
[c] Centre for Health and Social Practice, Waikato Institute of Technology, Private Bag 3036, Waikato Mail Centre, Hamilton 3240, New Zealand
[d] School of Nursing & Midwifery, University of Technology Sydney, Faculty of Health, 235 Jones St, Ultimo, NSW 2007, Australia

ARTICLE INFO

Keywords:
Virtual reality
Clinical decision-making
Nursing student
Undergraduate
Integrative review

ABSTRACT

Background: Clinical decision making is an essential cognitive skill in nursing. It is a process undertaken daily by nurses as they make judgements about patient care and manage complex issues as they arise. Virtual reality is an emerging technology that is increasingly being used pedagogically to teach non-technical skills including CDM, communication, situational awareness, stress management, leadership, and teamwork.
Objective: The objective of this integrative review are to synthesise the research findings regarding the impact of virtual reality on clinical decision making in undergraduate nurses.
Design: An integrative review using Whittemore and Knafl's framework for integrated reviews.
Data sources: An extensive search was conducted of healthcare databases including CINAHL, Medline and Web of Science between 2010 and 2021 using the terms virtual reality, clinical decision and undergraduate nursing.
Review methods: The initial search located 98 articles. After screening and checking for eligibility, 70 articles were critically reviewed. Eighteen studies were included in the review and were critically appraised using the Critical Appraisal Skills Program checklist for qualitative papers and McMaster's Critical appraisal form for quantitative papers.
Results: Research in the use of VR has demonstrated its potential to improve undergraduate nurses' critical thinking, clinical reasoning, clinical judgement and clinical decision-making skills. Students perceive these teaching modalities to be beneficial to the development of their clinical decision-making ability. There is lack of research related to the use of immersive virtual reality in developing and enhancing undergraduate nursing students' clinical decision-making skills.
Conclusion: Current research on the impact of virtual reality on the development of nursing CDM has demonstrated positive results. VR is one pedagogical approach that could further assist, however, there are no identified studies that focus on its impact in developing CDM, therefore further studies are required to address this gap in the literature.

1. Introduction

Virtual reality is an emerging technology with applications spanning a wide range of fields including education, nursing, medicine and rehabilitation (Ludlow, 2015). Virtual reality is defined as an approach that "allows the user to subjectively be involved and become immersed within a computer-generated environment. As the physical world is hidden, the user perceives the virtual environment as real, while the acquired sense of presence enhances the feeling of immersion" (Protopsaltis and Papagiannakis, 2020, p. 2). Virtual reality acts as a cognitive tool which offers an alternative way to see and experience information more easily. Virtual reality has been used for model building, problem solving (Mclellan, 1998) and simulated learning experiences (Ludlow, 2015). In nursing, virtual reality has become a widely accepted pedagogy for teaching many non-technical skills such as communication, situational awareness, stress management, leadership, team-work and, to a lesser extent, clinical decision-making (Foronda and Bauman, 2014; Peddle et al., 2016).

* Corresponding author at: Building 41, Northfields Ave, Wollongong, NSW 2516, Australia.
E-mail addresses: cjans@uow.edu.au (C. Jans), Fiona.bogossian@usc.edu.au (F. Bogossian), Patrea.Andersen@wintec.ac.nz (P. Andersen), tracy.levett-jones@uts.edu.au (T. Levett-Jones).

https://doi.org/10.1016/j.nedt.2023.105767
Received 9 November 2022; Received in revised form 1 February 2023; Accepted 20 February 2023
Available online 27 February 2023

In nursing, clinical decision making is critical for safe and effective patient care (Deegan, 2013). Clinical decision making is a process undertaken by nurses on a daily basis as they make judgements about patient care and manage issues that arise (Standing, 2020). Clinical decision making is defined as "a complex process of observation, information processing, critical thinking, evaluating evidence, applying knowledge, problem solving, reflection, judgement to select best option from available choices to optimize patients' health and minimize potential harm" (Standing, 2010, p. 7). Although some studies have focussed on the development of clinical decision making in undergraduate nursing students when participating in simulation, (Foronda et al., 2018; Harrington et al., 2018; Thompson et al., 2013; Thompson and Stapley, 2011), few studies have focused on the development of clinical decision making using virtual reality.

This paper will critically appraise and synthesise the literature related to the impact of virtual reality on clinical decision making in undergraduate nurses.

1.1. Background

Virtual reality (VR) can be traced back to the 1960s where cameras and projectors were used to create an immersive, interactive environment (Boyles, 2017). However, it was not until Lanier, a computer scientist and researcher, coined the term in 1987 that VR's popularity began to increase. Despite this, barriers such as cost, technical difficulties and poor graphics, computing power and accessibility contributed to a slow uptake of this technology (Slater, 2018). The past several decades has seen VR increase in both utility and popularity of VR (Jerald, 2015), with increasing recognition of it as a promising technology for implementation in higher education (Luo et al., 2021).

Currently there exist many forms of VR utilising different levels of immersion, from desktop applications to full immersive VR incorporating stereoscopic, head mounted displays with motion tracking. The increase in the use of desktop VR technology has seen many educators integrating this form of VR into their instruction (Merchant et al., 2014); utilising applications, such as Second Life®, to replicate real life settings where users can actively engage in realistic activities (Merchant et al., 2014). In nursing, creation of vSim for Nursing®, a web based single user application, provides users opportunities for students to practice cognitive skills (Foronda et al., 2017). Also gaining popularity in nursing education is the use of serious games (SG), computer based games designed for the purpose of providing education (Gentry et al., 2019). SGs provide immersive and virtual environments which provide the user with realistic opportunities to practice and develop a variety of skills and competencies (Petit dit Dariel et al., 2013). Few studies have focused on the use of immersive 3D VR in education and how it assists students' learning both technical skills and cognitive skills such as decision making.

Clinical decision making (CDM) is a process that includes a nurse's ability to think critically, clinically reason and make clinical judgements. Critical thinking is a controlled and purposeful activity that uses well-reasoned strategies to arrive at the results needed (Alfaro-LeFevre, 2015). Clinical reasoning is "a systematic and cyclical process" (Levett-Jones, 2017, p. 4) used to think about issues of patient care (Alfaro-LeFevre, 2015), whilst clinical judgement refers to the outcome of both critical thinking and clinical reasoning and the conclusion, decision or opinion reached (Alfaro-LeFevre, 2015). Critical thinking, clinical reasoning and clinical judgement, therefore, inform nurses CDM through purposeful and informed thinking undertaken in a systematic and cyclical way, using their judgement to arrive at a decision which can then be acted upon. These cognitive domains, therefore, are interrelated and used by nurses in every day practice to ensure safe patient care (Guerrero, 2019).

2. Methods

2.1. Aims

The aims of this review are to: 1) review methodological approaches and tools used to assess the development of CDM; and 2) to appraise the published literature on VR to determine its impact on the development of CDM in undergraduate nursing students.

2.2. Design

The review was conducted using Whittemore and Knafl's (2005) framework for integrated reviews. This approach was selected as it allows for the inclusion of theoretical literature from both qualitative and quantitative studies. Integrated reviews allow also for a comprehensive review of what is known about a topic so as to provide directions for future studies (Torraco, 2016).

The steps used in this review were: (1) problem identification, (2) literature search, (3) data evaluation, (4) data analysis and (5) presentation (Whittemore and Knafl, 2005).

2.2.1. Problem identification

In the current educational climate, nurse educators must consider innovative and accessible teaching and learning approaches that assist students to develop the requisite skills to enable their transition from novice practitioner to work ready clinician (Butt et al., 2018; Fealy et al., 2019). VR is an emerging technology with the potential to meet this need; however, the use and effectiveness of VR technology as a pedagogical approach in nursing education is not well understood. Current research centres on the use of VR in developing psychomotor (Breitkreuz et al., 2021; Chang et al., 2020; Lai and Chang, 2020) and communication skills (Hara et al., 2021), and focusing on evaluating user perceptions (Hardie et al., 2020; Saab et al., 2021; Taçgın, 2020; Thompson et al., 2020).

The development of CDM has been studied extensively in the context of computer based virtual simulation, such as serious gaming, Laerdal's vSim® for Nursing and FIRST2ACT™ (Adhikari et al., 2021; Padilha et al., 2019). Absent from the literature, however, is whether immersive 3D VR assists nursing students in developing CDM skills.

2.2.2. Literature search

2.2.2.1. Search methods. The literature search was conducted using SCOPUS, Web of Science, Cumulative Index of Nursing and Allied Health Literature (CINAHL), and Medline databases using the following terms: virtual reality, clinical decision making and undergraduate nurses (see Table 1) and synonyms. Truncations and Boolean operators "OR" and "AND" were applied. Following this, hand searching of reference lists of included papers was undertaken.

2.2.2.2. Search limits. The search was limited to peer-reviewed papers published between January 2011 and December 2021.

2.2.2.3. Inclusion criteria. Articles were included if they reported on English language primary studies that involved undergraduate nursing students, VR as an intervention and CDM as an outcome.

Table 1
Search terms.

Virtual reality	Clinical decision making	Undergraduate nurses
virtual reality/virtual simulation/VR/virtual environment/gaming/ augmented reality/AR/ immersive/immersion	Clinical decision/non-technical skills/clinical judgement/clinical reasoning/cognitive skill*/critical thinking	Student nurs*/ undergraduate nurs*/pre-registration nurs*/nurs* education

2.2.2.4. Exclusion criteria. Articles were excluded if they did not report on primary studies related to undergraduate nursing students, VR as an intervention and CDM as an outcome, or if they were systematic or literature reviews, discussion, or descriptive papers.

2.2.2.5. Search outcomes. Ninety-eight (98) articles that matched the search terms were identified. Screening for duplication reduced the number of relevant articles to 89. These articles were then reviewed by title and abstract against the inclusion/exclusion criteria and a further 19 articles that did not meet the inclusion criteria were removed. The outcomes of this stage of the process were then discussed with the other authors. The remaining 70 articles were then reviewed in their entirety. Of these, a total of 14 studies were identified to have met all of the inclusion criteria. The reference lists of these 14 eligible studies were then hand searched which resulted in four additional studies that met the inclusion criteria. A total of 18 studies (Fig. 1) were included in the review of which, three were mixed methods, four were qualitative and eleven were quantitative studies. Studies were independently reviewed by a second author against the inclusion/exclusion criteria.

2.2.3. Quality appraisal

Each included study was assessed for quality using appraisal tools appropriate for quantitative, qualitative or mixed-methods research. Quantitative research was assessed using Bowling's (2014) checklist which included 20 evaluation criteria. Qualitative studies were appraised using the Qualitative Assessment and Review Instrument (QARI) critical appraisal instrument (Pearson et al., 2009), whilst the remaining mixed methods studies were reviewed using the Mixed Methods Appraisal Tool (MMAT) (Hong et al., 2018).

All included studies were independently assessed by two authors (CJ & FB) and any discrepancies were reviewed and resolved by a third author. For each appraisal tools, each criterion deemed to have been met in a paper was allocated one point. Points were then tallied to provide an overall quality score. All quantitative studies were scored out of a

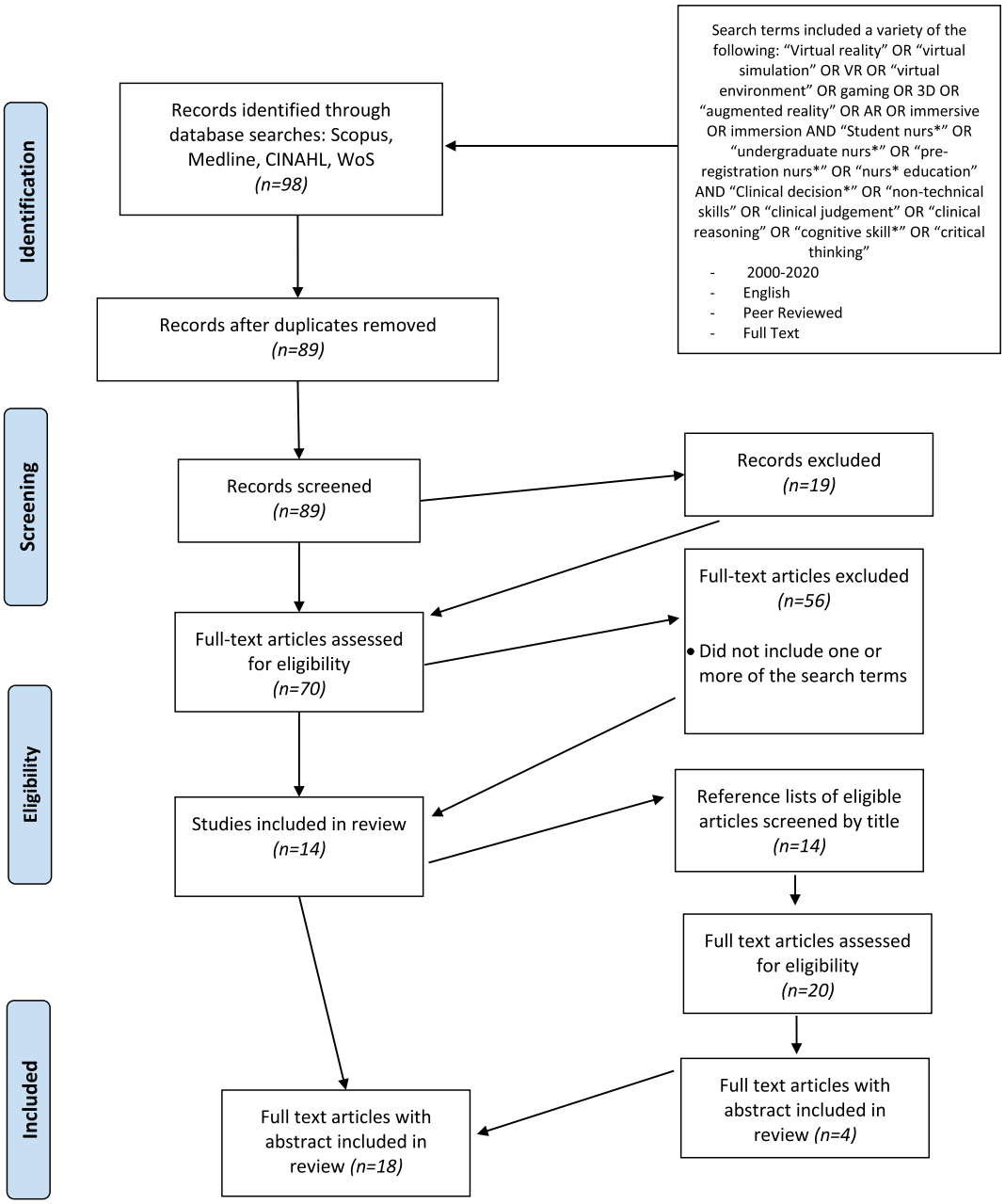

Fig. 1. PRISMA diagram.

maximum of 20, all qualitative studies were scored out of a maximum of 10 and all mixed methods studies were scored out of a maximum of 15. For the 11 quantitative studies, the scores ranged from 11 to 15. The range of scores for the four qualitative studies ranged from seven to eight. For the three mixed methods studies, the results ranged from six to eight. As none of the appraisal tools used indicated a specific score to determine quality of the article, all articles were included in this paper regardless of their score, with research of low rigour and relevance contributing less to the final analytical process.

Appraisal of the quantitative studies identified that all 11 studies clearly stated the aims, objectives, ethical considerations and conclusions. Ten of the 11 studies clearly outlined dependent and independent variables, utilised appropriate methods and statistical analyses, with reported results related to the hypotheses and literature, and limitations discussed (Table 2). Less than half of the studies *(n = 4)*, however, clearly specified a research question, and data availability for scrutiny or reanalysis was not included in any of the studies.

For the qualitative studies, all four studies demonstrated congruity between methodology and methods used to collect data, between methodology and representation and analysis of data and between methodology and interpretation of results. Additionally, all studies adequately represented participants and their voices, documented evidence of ethical approval, and conclusions drawn flowed from the analysis or interpretation of data. However, two of the studies, demonstrated congruity between the stated philosophical perspective and research methodology used and only one study addressed the influence of the researcher on the research. None of the studies provided a statement locating the researcher culturally or theoretically.

For the three mixed methods studies, each identified a clear research question, utilised a qualitative approach that was appropriate to answer the research question, and data collection methods were appropriate to answer the research question. For two studies, the findings were adequately derived from the data and measurements and statistical analysis was appropriate. None of the studies, however, provided a rationale for using a mixed methods design and outputs of the integration of qualitative and quantitative components were not adequately interpreted.

2.2.4. Data analysis

Data from the included studies was extracted and tabulated in a spreadsheet. Data extraction included author, year, country, aims/objectives, participants, methods and main findings (Table 3). Information was collated under the four domains of critical thinking, clinical reasoning and clinical judgement and CDM. VR technology used within the studies included virtual desktop simulation, virtual patients and serious gaming. One study utilised head mounted display.

3. Results

3.1. Critical thinking

In a study by Kang et al. (2020), a one-group, pre-test post-test design was used to test critical thinking, self-directed learning ability and simulation effectiveness of a game-based approach to assess students' performance in ECGs. Critical thinking disposition was measured using a 27 item instrument (Yoon, 2004). The instrument achieved high reliability for both pre-test and post-test (Cronbach's α = 0.85–0.88). The results demonstrated the experimental group outperformed the control group on critical thinking tendency and the mean scores of the experimental group were higher than those of the control group suggesting utilisation of game-based learning situates learners in decision-making contexts that reflect real cases.

Chang et al. (2020) utilised a quasi-experimental design to compare critical thinking disposition and self-directed learning using a contextualised game for teaching ECGs to 4th year nursing students. Critical thinking disposition was measured using a six item instrument (Chang

Table 2
Quality appraisal of included studies by study design.

Criteria	Yes	No
Quantitative studies critical appraisal checklist (Bowling, 2014)		
Aims and objectives clearly stated	11	0
Hypothesis/research questions clearly specified	5	6
Dependent and independent variables clearly stated	10	1
Variables adequately operationalized	8	3
Design adequately described	9	2
Method appropriate	10	1
Instruments used tested for reliability and validity	7	4
Source of sample, inclusion/exclusion, response rates described	10	1
Statistical errors discussed	1	10
Ethical considerations	11	0
Was the study piloted	3	8
Statistically analysis appropriate	10	1
Results reported and clear	9	2
Results reported related to hypothesis and literature	10	1
Limitations reported	10	1
Conclusions do not go beyond limit of data and results	11	0
Findings able to be generalised	0	11
Implications discussed	8	3
Existing conflict of interest with sponsor	0	11
Data available for scrutiny and reanalysis	0	11
Qualitative Studies critical appraisal checklist (Pearson et al., 2009)		
Congruity between stated philosophical perspective and research methodology	2	2
Congruity between methodology and research question or objectives	3	1
Congruity between methodology and methods used to collect data	4	0
Congruity between methodology and representation and analysis of data	4	0
Congruity between methodology and interpretation of results	4	0
There is a statement locating the researcher culturally or theoretically	0	4
The influence of the researcher on the research, and vice-versa is addressed	1	3
Participants and their voices are adequately represented	4	0
Ethical according to current criteria, evidence of ethical approval	4	0
Conclusions drawn flow from analysis or interpretation of data	4	0
Mixed Methods Appraisal Tool (MMAT) (Hong et al., 2018)		
S1. Are there clear research questions?	3	0
S2. Do the collected data allow to address the research questions?	3	0
1.1. Is the qualitative approach appropriate to answer the research question?	3	0
1.2. Are the qualitative data collection methods adequate to address the research question?	3	0
1.3. Are the findings adequately derived from the data?	2	1
1.4. Is the interpretation of results sufficiently substantiated by data?	1	2
1.5. Is there coherence between qualitative data sources, collection, analysis and interpretation?	0	3
2.1. Is randomization appropriately performed?	0	3
2.2. Are the groups comparable at baseline?		
2.3. Are there complete outcome data?	0	3
2.4. Are outcome assessors blinded to the intervention provided?	0	3
2.5 Did the participants adhere to the assigned intervention?	0	3
3.1. Are the participants representative of the target population?	0	3
3.2. Are measurements appropriate regarding both the outcome and intervention (or exposure)?	1	2
3.3. Are there complete outcome data?	1	2
3.4. Are the confounders accounted for in the design and analysis?	0	3
3.5. During the study period, is the intervention administered (or exposure occurred) as intended?	1	2
4.1. Is the sampling strategy relevant to address the research question?	1	2
4.2. Is the sample representative of the target population?	1	2
4.3. Are the measurements appropriate?	2	1
4.4. Is the risk of nonresponse bias low?	0	3
4.5. Is the statistical analysis appropriate to answer the research question?	2	1
5.1. Is there an adequate rationale for using a mixed methods design to address the research question?	0	3
5.2. Are the different components of the study effectively integrated to answer the research question?	1	2
5.3. Are the outputs of the integration of qualitative and quantitative components adequately interpreted?	0	3
	0	3

(*continued on next page*)

Table 2 (*continued*)

Criteria	Yes	No
5.4. Are divergences and inconsistencies between quantitative and qualitative results adequately addressed?		
5.5. Do the different components of the study adhere to the quality criteria of each tradition of the methods involved	3	0

et al., 2020). The instrument achieved high reliability (Cronbach's α = 0.88–0.79). The results identified that critical thinking disposition scores were not significantly different between pre and post virtual simulated learning.

Limitations were identified in both of the above studies. Use of a single site, linguistic and cultural barriers, as well as the use of a self-reporting instrument, may have impacted Kang et al. (2020). A small sample size and the novelty factor of using virtual simulation may have influenced Chang et al. (2020) results.

3.2. Clinical reasoning

Nine studies focused on the impact of virtual reality on clinical reasoning in undergraduate nursing students. Of these, three used valid data collection instrument with Cronbach α measuring 0.892 (Georg et al., 2018), 0.931 (Georg et al., 2019) and 0.882 and 0.970 (Padilha et al., 2019). Five studies (Forsberg et al., 2011; Johnsen et al., 2016; Johnsen et al., 2018; Koivisto et al., 2016b; Koivisto et al., 2016a) used Likert scale instruments developed specifically for the study. A final study utilised script concordance tests (SCTs) (α = 0.75), that compared the decisions made by students against those of a panel of experts in addition to a self-assessment (Blanié et al., 2020).

Five of the nine studies focussed on clinical reasoning and serious gaming (Blanié et al., 2020; Johnsen et al., 2016; Johnsen et al., 2018; Koivisto et al., 2016b; Koivisto et al., 2016a), two reviewed the development of a virtual version and use of the Lasater Clinical Judgement Rubric (vpLJCR) in assessing clinical reasoning in nursing students (Georg et al., 2018; Georg et al., 2019), and two studies investigated clinical reasoning using virtual patients and virtual simulation (Forsberg et al., 2011; Padilha et al., 2019).

Three of the five studies that investigated clinical reasoning and serious gaming utilised the clinical reasoning cycle (Levett-Jones, 2017), identifying a strong correlation between gaming and the clinical reasoning process (Johnsen et al., 2018; Koivisto et al., 2016b; Koivisto et al., 2016a). Koivisto et al. (2016a) identified that students learnt mostly about collecting cues and implementing nursing interventions according to symptoms (Koivisto et al., 2016a), whilst a second study (Koivisto et al., 2016b) ascertained a strong relationship between application of nursing knowledge and usability, exploration and reflection. The findings from both of these studies support the use of serious gaming to develop nursing students' clinical reasoning skills. Johnsen et al. (2016) concluded that serious gaming was perceived as being realistic, clinically relevant, at an adequate level of complexity for intended users, and that it could serve as a supplement to traditional learning approaches used in laboratory and clinical settings. Johnsen et al. (2018) focused on the perceptions of nursing students, further supporting their earlier findings above. Results from these studies suggest students perceive learning through serious gaming as educationally valuable and believe that it improves their clinical reasoning skills.

Blanié et al. (2020) compared the use of virtual simulation gaming with traditional teaching methods during debriefing to develop clinical reasoning in nursing students. In contrast to Koivisto et al. (2016b) and Koivisto et al. (2016a), no significant educational differences were observed between the two groups immediately after or one month post the simulation experiences. Satisfaction and motivation was highly valued in both groups, but were significantly greater in the serious gaming group (Blanié et al., 2020), supporting Johnsen et al. (2018) and Johnsen et al. (2016) view that the use of serious gaming is perceived as educationally advantageous.

Two studies reviewed the development and use of a virtual adaptation of the Lasater Clinical Judgement Rubric (vpLJCR) in assessing clinical reasoning in nursing students (Georg et al., 2018; Georg et al., 2019). Georg et al. (2018) developed, then tested the vpLCJR rubric for its ability to capture clinical reasoning during nursing student encounters with virtual patients. Results from this study identified that different dimensions and development descriptors of the vpLCLR are able to capture the clinical reasoning process, indicated by the distribution of students responses across all dimensions of the instrument (Georg et al., 2018). Consistent reliability of the instrument was demonstrated with a Cronbach's α of 0.892 (Georg et al., 2018). The second study focused on determining the psychometric properties of the vpLCJR (Georg et al., 2019). An exploratory factor analysis of the rubric identified it consisted of three factors: understanding the patient, care planning and reflecting. A Cronbach's α of 0.931 across the 11 associated items indicated consistent reliability (Georg et al., 2019). The factor structure appears to reflect the clinical reasoning competence required for nursing students, indicating the different dimensions and development descriptors capture the various aspects of clinical reasoning (Georg et al., 2019). These studies indicate the development of the vpLCLR rubric is a reliable tool for measuring clinical reasoning skills in nursing students.

Forsberg et al. (2011) investigated nursing students' perceptions on the feasibility of using virtual patients for assessing clinical reasoning. Results indicated most participants responded positively to the use of virtual cases for assessment and agreed the use of virtual cases was an effective way to practice and assess clinical problem solving. Padilha et al. (2019) extended knowledge around clinical reasoning beyond immediate measures of student satisfaction. Using a randomized control trial (RCT), they evaluated the use of virtual simulation for improving knowledge retention, clinical reasoning, self-efficacy and satisfaction in nursing students. Results identified that virtual simulation improved knowledge retention and clinical reasoning over time. These findings support the use of virtual simulation and virtual patients for improving clinical reasoning and that students viewed the use of virtual simulation as a positive way to learn clinical reasoning, supporting previous results above.

3.3. Clinical judgement

Two studies investigated the use of virtual reality in developing clinical judgement in nursing students. One study aimed to evaluate nursing students' Clinical judgement using virtual simulation (Fogg et al., 2020), whilst the second explored application, advantages and challenges of mixed reality technology (Frost et al., 2020).

Fogg et al. (2020) investigated the virtual simulation performance of nursing students using self-perceived ratings on the Lasater Clinical Judgement Rubric over a sequence of 13 scenarios. Results indicated that students demonstrated significant improvements from the first virtual scenario to the final scenario overall. Within each dimension of the Lasater rubric, results indicated improvement in the dimensions of noticing, interpreting, responding and reflecting. Students also believed that they improved from the first scenario to the final scenario. These results indicate that use of virtual simulation is beneficial to learning and that students also perceive it to increase knowledge and clinical judgement.

Frost et al. (2020) utilised a descriptive evaluation design to survey nursing students' learning experiences with mixed reality technology. Students felt the experience provided a safe environment for learning and that it assisted them to develop their interpretation of the situation, recognition of physical cues and observation of the patient without time pressures or invasion of personal space.

Both studies identified limitations, including the use of a single site and cohort of students, that limited the generalisability of the findings, a focus on students' perceptions rather than more objective measures and a lack of student familiarity with the system and criteria that may have

Table 3
Methodological characteristics and summary of main findings of included studies.

Author, Year & Country	Study Design	Aim	Participants	Methods	Main findings
1. Chang et al. (2020) Taiwan	Quasi-Experimental design	Exploration and investigation of a contextualised game for teaching ECG	4th-year nursing students from two classes of a nursing school ($n = 72$)	Pre-test, post-test and interviews. Tests consisted of 6 items related to motivation, 7 items related to attitude, 9 items related to learning satisfaction and 6 items related to CT. All assessed using a 5 point Likert scale	Results indicated that CT disposition scores were not significantly different ($t = 0.439$, $p = 0.872$) between the pre virtual simulation (98.83 ± 9.44) and post virtual simulation (97.96 ± 9.81) learning, suggesting that CT improved but that this improvement was not significant
2. Kang et al. (2020) Korea	Pre-test, Post-test design	Compare CT disposition and self-directed learning ability before and after virtual simulation	Nursing students ($n = 47$)	One-group pre-test–post-test. CT disposition assessed using 27 item instruments consisting of 7 subscales and measured using a 5 point Likert scale	Results demonstrated the experimental group outperformed the control group on CT tendency ($F = 629.76$, $p < 0.001$) and the mean scores of the experimental group ($M = 4.21$) was higher than that of the control group ($M = 1.95$) suggesting utilisation of game-based learning situates learners in decision-making contexts that reflect real cases
3. Blanié et al. (2020) France	RCT	Compare the respective value of simulation using serious gaming (SG) versus traditional teaching (TT) methods to improve CR skills in detecting patient deterioration	2nd year nursing students ($n = 143$)	Script concordance tests (SCTs). 80 SCTs developed by experts in the topic. Students assessed against these SCTs	Results determined that no significant educational differences were observed between the two groups immediately after the learning ($p = 0.43$) or one month post the simulation experiences ($p = 0.77$). However, satisfaction and motivation was highly valued in both groups, but was significantly greater in the serious gaming group ($p < 0.05$) and students across both groups perceived their knowledge of the CR process to have increased
4. Forsberg et al. (2011) Sweden	Observational Design	Investigate nursing students' opinions on the use of Virtual Patients (VP) for assessing CR and CDM skills	Three separate nursing courses across 2 universities ($n = 77$)	Questionnaire purposefully developed for the study. 23 item questionnaire using one to six check boxes	Results identified that most participants had a positive response to the use of virtual cases for assessment, considering it a good learning experience and form of assessment. Most students agreed use of virtual cases was a good way to practice and assess clinical problem solving (median = 5). The study did not specifically report on whether students perceived interaction with virtual patients assisted with development of their CR
5. Georg et al. (2018) Sweden	Two-phase design using abductive and deductive analyses	Develop and test a rubric to assess nursing students CR when encountering virtual patients	2nd year nursing students ($n = 125$)	Questionnaire and deductive analysis of free text responses	The study identified that different dimensions and development descriptors of the vpLCLR can capture the CR process, with results showing that student responses were distributed over all dimensions of the instrument ($M = 29.75$, $SD = 6.2$)
6. Georg et al. (2019) Sweden	Non-experimental design	Determine the psychometric properties of the virtual patient version of the Lasater Clinical Judgement Rubric (vpLCJR)	2nd year nursing students, enrolled in a course that included both theoretical and clinical aspects ($n = 130$)	Grading Rubric (vpLCJR) assessing 11 dimensions across 4 phases of CR. Free-text short summaries	The suggested factors explained 81.8 % of the variance and the new three factor structure appears to reflect the CR competence required for nursing students, indicating the different dimensions and development descriptors capture the various aspects of CR
7. Johnsen et al. (2016) Norway	Qualitative deductive content analysis	Describe the design, development and usability evaluation of a video based SG for teaching CR and CDM to nursing students caring for people with COPD in the home healthcare setting	6 participants. 2 x 3rd year nursing students, 2 x lecturers and 2 x RN's	Survey Questionnaire and interview.	The SG was perceived as being realistic, clinically relevant with appropriate complexity. Participants identified the SG could supplement more traditional teaching approaches in laboratory and clinical settings
8. Johnsen et al.	Pilot Study	Assess nursing students perceptions of video-based	2nd year nursing students their Bachelor of Nursing	Questionnaire purposefully developed for the study, consisting	Results indicated that participants who completed the home

(*continued on next page*)

Table 3 (*continued*)

(2018) Norway		serious gaming as well as perceptions of usability, individual factors and preferences of this kind of e-learning resource	program across two campuses ($n = 249$)	of open and closed questions and interviews	healthcare simulation strongly agreed or agreed it improved their CR ($p = 0.038$) and CDM ($p = 0.006$) as opposed to those completing the medical-surgical simulation. Participants in the home healthcare simulation strongly disagreed or disagreed they would prefer role play based cases instead of gaming as opposed to those completing the medical surgical course ($p = 0.018$).
9. Koivisto et al. (2016b) Finland	Cross-Sectional Descriptive design	Investigate nursing students experiences of learning CR by playing a 3D simulation game	Nursing students enrolled in a surgical nursing course ($n = 166$)	Questionnaire purposefully developed for the study using a 5 point Likert scale.	Results reported that students' perceived they learnt mostly about collecting cues from interviewing ($M = 3.31$, $SD = 0.945$) and implementing nursing interventions according to symptoms ($M = 3.3$, $SD = 0.873$). Students perceived they learnt least evaluating the effectiveness of interventions ($M = 2.91$, $SD = 0.977$). The strongest correlation was between identifying issues and establishing goals ($r = 0.79$) as well as a strong correlation between applying knowledge and identifying issues ($r = 0.552$).
10. Koivisto et al. (2016a) Finland		Describe and explain how nursing students can learn CR by playing a simulation game	Nursing students who participated in a surgical nursing course at two universities ($n = 166$)	One-group pre-test–post-test. CT disposition assessed using 27 item instruments consisting of 7 subscales and measured using a 5 point Likert scale.	Results identified participants mainly learnt to take action and collection information. Information collecting was best learnt through interviewing ($m = 3.31$). There was a strong correlation between learning to identify issues and establishing goals ($r = 0.79$) and a strong correlation between applying knowledge and identifying issues ($r = 0.552$).
11.Padilha et al. (2019) Portugal	RCT	Evaluate the effect of virtual simulation on nursing students' knowledge retention, CR, self-efficacy and satisfaction.	Undergraduate 2nd year nurses ($n = 42$)	Pre-test Post -test, MCQ	The experimental group demonstrated significantly better improvements in knowledge retention ($p = 0.001$) and learning satisfaction ($p < 0.001$) than the control group
12.Fogg et al. (2020) USA	Pilot Study using a repeated measures design	Evaluate CJ skills of nursing students using virtual simulation	Senior level nursing students enrolled in the child health nursing course ($n = 234$)	Lasater Clinical Judgement Rubric (LCJR)	Results indicated that participants had significant improvement from the first case to the last case ($p = 0.000$). There was also significant improvement over the 4 dimensions of noticing ($p = 0.000$), interpreting ($p = 0.002$), responding ($p = 0.001$) and reflecting ($p = 0.01$). Findings suggest virtual simulation is beneficial in development of CJ
13. Frost et al. (2020) Australia	Descriptive evaluation design	Explore the application, advantages and challenges of mixed reality in nursing education and its contribution to enhanced learning.	Students enrolled in 2nd year nursing degree undertaking a core theoretical nursing unit ($n = 96$)	Questionnaire, purposefully developed for the study, consisting of 6 subscales using a 4 point Likert scale.	Participants identified that use of HMD's and virtual simulation increased engagement in learning and developed their clinical judgement, especially in the areas of noticing and interpreting, visualising, assessment and reflection
14.Atthill et al. (2021) Canada	Experimental design	Explore nursing students perceived confidence and anxiety for engaging in CDM was impacted by virtual asynchronous debriefing	Nursing students ($n = 64$) in the 3rd semester of their practical nursing program	Questionnaire (NASC-CDM). 27-item questionnaire using a 6 point Likert scale	Asynchronous debriefing strategy had a greater influence on decreasing anxiety than face-to-face (F2F) debriefing ($p = 0.041$). Asynchronous and F2F debriefing both enhanced self-confidence ($p = 0.004$) and reduced anxiety ($p = 0.001$) in relation to supporting students to select and implement nursing actions. Both methods of debrief supported the essential

(*continued on next page*)

Table 3 (*continued*)

					aspect of CDM related to students perceived ability to know and act.
15. Forbes et al. (2016) Australia	Observational design	Explore the feasibility and reliability of HMVC recordings to augment observational data and enhance feedback to students on their clinical decision-making.	Nursing students enrolled in a final year clinical unit, who were completing a clinical placement at the hospital ($n = 31$)	Observational data collection tool used to collect behavioural data. A 17-item questionnaire used to collect participants experiences.	Findings suggest that use of HMVC to provide extensive feedback and observed student CDM behaviours has the potential to enhance CDM skills.
16. Garcia-Viola et al. (2019) Spain	Quasi-experimental design	Determine the influence of gamification on decision making in nursing students	Students enrolled in a basic and advanced life support subject ($n = 191$)	Questionnaire (MDMQ). 22 item questionnaire assessing 4 dimensions using a 4 point Likert scale.	Results identified the experimental group performed better than the control group in behaviour patterns: vigilance ($p = 0.001$), buck passing ($p = 0.000$) and procrastination ($p = 0.000$). Findings suggest gamification has a significant impact on CDM.
17. McCallum et al. (2011) UK	Exploratory Qualitative design	Explore nursing students decision making skills through the use of 3-D virtual environments	3rd year nursing students ($n = 5$)	Written communication from virtual simulation. Semi-structured interviews.	Findings demonstrated that the majority of decisions by participants were reactive not proactive. Interviews produced 2 themes: performing decision making and improving learning. Students identified learning about CDM came from two
18. Peddle (2015) Australia	Case study design	Explore nursing students learning regarding specific non-technical skills (NTS) following interactions with virtual patients (VPs).	First and 3rd year nursing students who had interacted with VPs ($n = 76$).	Focus groups and interviews.	Interactions with VPs developed knowledge and skills of all categories of NTS in varying degrees with communication the most developed skill. VPs facilitated understanding of decision making and highlighted decision making process.

influenced results.

3.4. Clinical decision making

Of the five studies investigating CDM, two studies utilised validated questionnaires using Likert scales to collect data with Cronbach α of 0.87 (Garcia-Viola et al., 2019) and 0.97 (Atthill et al., 2021). Two studies employed a qualitative approaches data collection included focus groups and semi-structured interviews (McCallum et al., 2011; Peddle et al., 2016). McCallum et al. (2011) analysed data using a seven-step process, whilst Peddle et al. (2016) analysed data using framework analysis. The final study collected data from camcorder glasses worn by participants in addition to an observational tool adapted from of Gaba's Simulation Tool (Forbes et al., 2016).

Two (Garcia-Viola et al., 2019; McCallum et al., 2011) utilised gaming to investigate nursing students' CDM skills. Forbes et al. (2016) explored the feasibility and reliability of head mounted video camera (HMVC) recordings to enhance feedback on nursing students CDM behaviours. Peddle (2015) investigated the use of virtual patients to assess nursing students' development of non-technical skills and Atthill et al. (2021) explored nursing students' perceptions of confidence and anxiety during CDM using virtual asynchronous debriefing.

Garcia-Viola et al. (2019) explored CDM in the areas of vigilance, 'buck passing' and procrastination. Results indicated that experimental group scored higher in the area of vigilance, however, they demonstrated lower average scores in the areas of 'buck passing' and procrastination than the control group. McCallum et al. (2011) explored CDM skills using a 3D simulation game. They identified students were able to make decisions for each patient, however, decisions were mostly reactive rather than proactive. Individual interviews, identified that participants learnt decision making from two perspectives, theory from the classroom and experience in clinical practice (McCallum et al., 2011). Participants perceived the decisions made in the 3D simulation mimicked real scenario situations and developed their confidence in making decisions (McCallum et al., 2011). These findings indicate the use of gamification could be an important element in the promotion and practice of CDM in nursing education.

Forbes et al. (2016) conducted a pilot study to explore the feasibility and reliability of head mounted video camera (HMVC) recordings to supplement observational data and enhance feedback to nursing students on their CDM behaviours. Results revealed that three of the eight participants who completed all three simulations, demonstrated improvement from the first to the final exercise. A further three participants scored less in the second compared to the first exercise, but improved in the final exercise, with two of these participants achieving their highest individual scores in exercise 3. Results indicated the majority of participants felt encouraged to solve questions and were motivated to engage in reflection and constructive critique. Few participants felt that HMVC recording and feedback enhanced their learning (Forbes et al., 2016). Results from this study varied in terms of exposure and outcomes. Whilst head mounted displays have the potential to enhance CDM skills, further investigation is needed. Additionally, the small sample size limits the generalisability of the findings to other populations and a lack of experience in simulation may have contributed to the unsatisfactory performance of participants when responding to the deteriorating patient, potentially impacting the results.

Peddle et al. (2016) explored the use of virtual patients to determine what nursing students learnt about non-technical skills, including CDM. Findings revealed that participants acknowledged interactions with virtual patients facilitated their understanding of decision making, reporting interactions made them stop and think about decisions and potential consequences rather than just acting.

Atthill et al. (2021) explored how perceptions of self-confidence and anxiety during CDM was influenced by virtual asynchronous versus face to face (F2F) debriefing. Pre and post-test comparison indicated virtual asynchronous debriefing strategy had a greater influence on decreasing student anxiety than F2F debriefing with participants demonstrating increased self-confidence and decreased anxiety scores compared to the F2F group.

Limitations were identified for all studies. Two common limitations included small sample sizes (Atthill et al., 2021; Garcia-Viola et al.,

2019; McCallum et al., 2011) and results obtained through self-reporting from participants (Atthill et al., 2021; Garcia-Viola et al., 2019; Peddle et al., 2016) potentially providing an unreliable indication of students' actual knowledge, skill and CDM ability.

4. Discussion

The aims of this integrative review were to synthesise the research findings regarding the impact of virtual reality on CDM in undergraduate nurses and review related methodological approaches. Conclusive studies on the use of immersive VR in developing undergraduate nursing students CDM were lacking. This review, however, did identify that the use of virtual simulation and serious gaming can assist undergraduate nursing students in developing their CDM skills.

Virtual simulation facilitates effective learning when focused on the learner's own experiences to identify and solve problems in a given context (Shin et al., 2019). Virtual simulation provides a safe learning environment for students to apply their knowledge and practice skills without posing a risk to patients (Foronda et al., 2017). Many of the included studies on the use of virtual simulation identified that it improved knowledge, clinical reasoning and CDM and was perceived by participants to be an effective learning experience.

As with virtual simulation, serious gaming has the potential to offer a safe, reliable and effective learning experience (dit Dariel et al., 2013), enhance motivation and encourage learners to be keen participants in the learning process. The included studies focussing on serious gaming identified it developed and improved clinical reasoning and CDM. Additionally, it was perceived to be realistic and relevant and an effective supplement to traditional training methods.

Simulation offers pertinent practice in the decision making process (Zulkosky et al., 2016) and has been studied in relation to virtual simulation and serious gaming, however, there is a paucity of research that has focussed on the relationship between immersive virtual reality and whether it assists in developing and enhancing undergraduate nurses CDM skills. In a systematic review, Plotzky et al. (2021) identified that VR has the potential to improve the theory-practice gap by conveying practical skills whilst integrating theory, while Chen et al. (2020) indicated that VR has the potential to improve knowledge in relation to other teaching methods. Given the increased utility and popularity of this modality, further research is needed to determine the impact of immersive VR on developing CDM in undergraduate nursing students.

This review also reviewed methodological approaches and tools used to assess the development of CDM. Self-reporting evaluation measures were a predominant form of data collection within the included studies (Atthill et al., 2021; Fogg et al., 2020; Forsberg et al., 2011; Frost et al., 2020; Garcia-Viola et al., 2019; Johnsen et al., 2018; McCallum et al., 2011; Peddle et al., 2016). There are many benefits of using self-reporting measures, particularly in qualitative research, when researchers are concerned with studying human characteristics (Razavi, 2001). Self-reporting yields information that would be impossible to gather any other way and can capture psychological attributes through explicit communication with participants (Polit and Beck, 2017). However, there are also disadvantages including validity and accuracy of what participants are reporting (Polit and Beck, 2017) as there is no real way for the researcher to determine whether participants are telling the truth or responding in a favourable way (LoBiondo-Wood and Haber, 2014), subjecting the research to response biases (Polit and Beck, 2017).

The eight studies utilising self-reporting evaluation methods identified strong positive student satisfaction with the use of virtual simulation or serious gaming in developing the four domains. However, many also acknowledged self-reporting may not reliably indicate whether there was improvement and that further research is required to determine whether use of virtual simulation and serious gaming does actually improve critical thinking, clinical reasoning, clinical judgement and CDM (Atthill et al., 2021; Fogg et al., 2020; Frost et al., 2020; Garcia-Viola et al., 2019; McCallum et al., 2011).

Data collection instruments used within the included studies were mixed. Seven of the eighteen studies utilised validated tools and discussed validity and reliability of the instrument, highlighting the instruments used in these studies consistently and reliably measured what they were designed too, increasing researchers confidence their results were relevant (Andrew and Halcomb, 2009). Reliability of most validated instruments were expressed using Cronbach's alpha, which estimates the extent to which varying items of an instrument are reliably measuring the critical characteristic (Polit and Beck, 2017). All studies citing Cronbach's alpha demonstrated strong reliability. Only two instruments, however, focussed on assessing CDM, reporting on students' perceptions through self-reporting measures.

Several studies developed instruments for the sole purpose of the study and were either pilot tested on students or reviewed by content experts/academics for content and construct validity prior to being used in the study. There are a number of approaches for assessing content validity such as use of an expert panel, however, there is no entirely objective method of ensuring sufficient content coverage of an instrument (Polit and Beck, 2017). Validity of an instrument is supported by evidence, whereby the more evidence gathered an instrument is measuring what it is intending too, the more confident a researcher will have in its validity (Polit and Beck, 2017). This suggests that instruments developed for the purpose of a study may not necessarily be reliable and valid, resulting in decreased confidence in the relevance of results. Future research, therefore, should focus on the development of a reliable instrument that specifically targets objectively measuring whether CDM improves through virtual reality.

5. Strengths and limitations

The review process was carried out using a robust integrative review methodology with a high degree of scientific integrity. However, some limitations exist. Firstly, the inclusion and exclusion criteria used means that some studies relevant to the topic may have been omitted. Secondly, a single reviewer completed the search, data collection, and extraction. Despite this, rigorous multiple checking of data extraction was completed throughout the review process. Lastly, analysis was derived from the findings without consideration of the quality of each study included. Although quality assessment is not an integral part of integrative review methodology (Whittemore and Knafl, 2005), this poses the risk that weaker studies may have been included.

6. Conclusion

This review has identified that current research exploring the impact virtual simulation and serious gaming in CT, CR, CJ and CDM has demonstrated generally positive results in teaching and enhancing these cognitive skills in undergraduate nursing students. CDM is an essential nursing skill and the complexity of decision making for nurses continually increases as patient acuity and technological advancements increase (Nibbelink and Brewer, 2018). This highlights the need for nursing schools to consider more innovative teaching methods to further develop and enhance CDM skills in undergraduate nurses. VR is one pedagogical approach that has the potential to assist in CDM development by facilitating the construction of a comprehensive learning experience thereby enhancing knowledge and skills development. This review of the literature highlights, more robust research is needed, to determine the effectiveness of 3D immersive virtual reality in developing, improving and enhancing undergraduate nursing students' clinical decision-making skills.

CRediT authorship contribution statement

Carley Jans - Conceptualization, methodology, formal analysis, investigation, data curation, writing – original draft preparation, writing

– review & editing, visualisation.

Fiona Bogossian – conceptualization, methodology, formal analysis, writing - original draft preparation, writing – reviewing & editing, supervision.

Patrea Andersen – conceptualization, methodology, formal analysis, writing – reviewing & editing, supervision.

Tracy Levett-Jones - Conceptualization, investigation, data curation, writing – review & editing.

Declaration of competing interest

The authors have no conflict of interest.

References

Adhikari, R., Kydonaki, C., Lawrie, J., O'Reilly, M., Ballantyne, B., Whitehorn, J., Paterson, R., 2021. A mixed-methods feasibility study to assess the acceptability and applicability of immersive virtual reality sepsis game as an adjunct to nursing education. Nurse Educ. Today 103. https://doi.org/10.1016/j.nedt.2021.104944, 104944-104944.

Alfaro-LeFevre, R., 2015. Critical Thinking, Clinical Reasoning, and Clinical Judgment E-Book: A Practical Approach. Elsevier Health Sciences.

Andrew, S., Halcomb, E.J., 2009. Mixed methods research for nursing and the health sciences. John Wiley & Sons, Incorporated. http://ebookcentral.proquest.com/lib/uow/detail.action?docID=547079.

Atthill, S., Witmer, D., Luctkar-Flude, M., Tyerman, J., 2021. Exploring the impact of a virtual asynchronous debriefing method after a virtual simulation game to support clinical decision-making. Clin. Simul. Nurs. 50, 10–18.

Blanié, A., Amorim, M.A., Benhamou, D., 2020. Comparative value of a simulation by gaming and a traditional teaching method to improve clinical reasoning skills necessary to detect patient deterioration: a randomized study in nursing students [Article]. BMC Med. Educ. 20 (1), 53 https://doi.org/10.1186/s12909-020-1939-6.

Bowling, A., 2014. Research methods in health: investigating health and health services. McGraw-hill education, UK.

Boyles, B., 2017. Virtual Reality and Augmented Reality in Education. Center For Teaching Excellence, United States Military Academy, West Point, Ny.

Breitkreuz, K.R., Kardong-Edgren, S., Gilbert, G.E., DeBlieck, C., Maske, M., Hallock, C., Lanzara, S., Parrish, K., Rossler, K., Turkelson, C., Ellertson, A., Brown, K.N., Swetavage, T., Werb, M., Kuchler, E.G., Saiki, L.S., Noe, S.R., 2021. A multi-site study examining the usability of a virtual reality game designed to improve retention of sterile catheterization skills in nursing students. Simul. Gaming 52 (2), 169–184. https://doi.org/10.1177/1046878120954891.

Butt, A.L., Kardong-Edgren, S., Ellertson, A., 2018. Using Game-based Virtual Reality With Haptics for Skill Acquisition. Clin. Simul. Nurs. 16, 25–32.

Chang, C.Y., Kao, C.H., Hwang, G.J., Lin, F.H., 2020. From experiencing to critical thinking: a contextual game-based learning approach to improving nursing students' performance in electrocardiogram training. Etr&D-Educ. Technol. Res. Dev. https://doi.org/10.1007/s11423-019-09723-x.

Chen, F.-Q., Leng, Y.-F., Ge, J.-F., Wang, D.-W., Li, C., Chen, B., Sun, Z.-L., 2020. Effectiveness of virtual reality in nursing education: meta-analysis. J. Med. Internet Res. 22 (9), e18290.

Deegan, J., 2013. A view from the outside: nurses' clinical decision making in the twenty first century. Aust. J. Adv. Nurs. 30 (4), 12–18. https://doi.org/10.3316/ielapa.405083351168144.

dit Dariel, O.J.P., Raby, T., Ravaut, F., Rothan-Tondeur, M., 2013. Developing the Serious Games potential in nursing education. Nurse Educ. Today 33 (12), 1569–1575.

Fealy, S., Jones, D., Hutton, A., Graham, K., McNeill, L., Sweet, L., Hazelton, M., 2019. The integration of immersive virtual reality in tertiary nursing and midwifery education: a scoping review. Nurse Educ. Today 79, 14–19. https://doi.org/10.1016/j.nedt.2019.05.002.

Fogg, N., Kubin, L., Wilson, C.E., Trinka, M., 2020. Using virtual simulation to develop clinical judgment in undergraduate nursing students. Clin. Simul. Nurs. 48, 55–58.

Forbes, H., Bucknall, T.K., Hutchinson, A.M., 2016. Piloting the feasibility of head-mounted video technology to augment student feedback during simulated clinical decision-making: an observational design pilot study. Nurse Educ. Today 39, 116–121.

Foronda, C., Bauman, E.B., 2014. Strategies to incorporate virtual simulation in nurse education. Clin. Simul. Nurs. 10 (8), 412–418.

Foronda, C.L., Alfes, C.M., Dev, P., Kleinheksel, A., Nelson Jr., D.A., O'Donnell, J.M., Samosky, J.T., 2017. Virtually nursing: emerging technologies in nursing education. Nurse Educ. 42 (1), 14–17.

Foronda, C.L., Swoboda, S.M., Henry, M.N., Kamau, E., Sullivan, N., Hudson, K.W., 2018. Student preferences and perceptions of learning from vSIM for Nursing™. Nurse Educ. Pract. 33, 27–32.

Forsberg, E., Georg, C., Ziegert, K., Fors, U.J.N.E.T., 2011. In: Virtual Patients for Assessment of Clinical Reasoning in Nursing—A Pilot Study, 31(8), pp. 757–762.

Frost, J., Delaney, L., Fitzgerald, R., 2020. Exploring the application of mixed reality in nurse education. BMJ Simul. Technol. Enhanc. Learn. 6 (4), 214–219.

Garcia-Viola, A., Garrido-Molina, J.M., Marquez-Hernandez, V.V., Granados-Gamez, G., Aguilera-Manrique, G., Gutierrez-Puertas, L., 2019. The influence of gamification on decision making in nursing students. J. Nurs. Educ. 58 (12), 718–722. https://doi.org/10.3928/01484834-20191120-07.

Gentry, S.V., Gauthier, A., Ehrstrom, B.L.E., Wortley, D., Lilienthal, A., Car, L.T., Dauwels-Okutsu, S., Nikolaou, C.K., Zary, N., Campbell, J., 2019. Serious gaming and gamification education in health professions: systematic review. J. Med. Internet Res. 21 (3), e12994.

Georg, C., Karlgren, K., Ulfvarson, J., Jirwe, M., Welin, E., 2018. A rubric to assess students' clinical reasoning when encountering virtual patients. J. Nurs. Educ. 57 (7), 408–415.

Georg, C., Welin, E., Jirwe, M., Karlgren, K., Ulfvarson, J., 2019. Psychometric properties of the virtual patient version of the lasater clinical judgment rubric [Article]. Nurse Educ. Pract. 38, 14–20. https://doi.org/10.1016/j.nepr.2019.05.016.

Guerrero, J.G., 2019. Practice rationale care model: the art and science of clinical reasoning, decision making and judgment in the nursing process. Open J. Nurs. 9 (2), 79–88.

Hara, C.Y.N., Goes, F.D.S.N., Camargo, R.A.A., Fonseca, L.M.M., Aredes, N.D.A., 2021. Design and evaluation of a 3D serious game for communication learning in nursing education. Nurse Educ. Today 100. https://doi.org/10.1016/j.nedt.2021.104846, 104846- 104846.

Hardie, P., Darley, A., Carroll, L., Redmond, C., Campbell, A., Jarvis, S., 2020. Nursing & Midwifery students' experience of immersive virtual reality storytelling: an evaluative study [Article]. BMC Nurs. 19 (1) https://doi.org/10.1186/s12912-020-00471-5. N.PAG-N.PAG.

Harrington, C.M., Kavanagh, D.O., Quinlan, J.F., Ryan, D., Dicker, P., O'Keeffe, D., Traynor, O., Tierney, S., 2018. Development and evaluation of a trauma decision-making simulator in oculus virtual reality. Am. J. Surg. 215 (1), 42–47.

Hong, Q.N., Fàbregues, S., Bartlett, G., Boardman, F., Cargo, M., Dagenais, P., Gagnon, M.-P., Griffiths, F., Nicolau, B., O'Cathain, A., 2018. The mixed methods appraisal tool (MMAT) version 2018 for information professionals and researchers. Educ. Inf. 34 (4), 285–291.

Jerald, J., 2015. The VR Book: Human-centered Design for Virtual Reality. Morgan & Claypool.

Johnsen, H.M., Fossum, M., Vivekananda-Schmidt, P., Fruhling, A., Slettebø, Å., 2016. Teaching clinical reasoning and decision-making skills to nursing students: design, development, and usability evaluation of a serious game. Int. J. Med. Inform. 94, 39–48.

Johnsen, H.M., Fossum, M., Vivekananda-Schmidt, P., Fruhling, A., Slettebø, Å., 2018. Nursing students' perceptions of a video-based serious game's educational value: a pilot study. Nurse Educ. Today 62, 62–68.

Kang, S.J., Hong, C.M., Lee, H., 2020. The impact of virtual simulation on critical thinking and self-directed learning ability of nursing students. Clin. Simul. Nurs. 49, 66–72.

Koivisto, J.-M., Multisilta, J., Niemi, H., Katajisto, J., Eriksson, E., 2016b. Learning by playing: a cross-sectional descriptive study of nursing students' experiences of learning clinical reasoning. Nurse Educ. Today 45, 22–28.

Koivisto, J.M., Haavisto, E., Niemi, H., Katajisto, J., Multisilta, J., 2016a. Elements explaining learning clinical reasoning using simulation games. Int. J. Serious Games 3 (4), 29–43. https://doi.org/10.17083/ijsg.v3i4.136.

Lai, C., Chang, Y.-M., 2020. In: A Testing Case of Simulation Learning in Nursing by Virtual Reality - Subcutaneous Injection Training, Vol. 12555. Springer International Publishing, pp. 109–118. https://doi.org/10.1007/978-3-030-63885-6_13.

Levett-Jones, T., 2017. Clinical Reasoning: Learning to Think Like a Nurse. Pearson Education Australia.

LoBiondo-Wood, G., Haber, J., 2014. Reliability and validity. In: Nursing Research : Methods and Critical Appraisal for Evidence-based Practice, 8th edition. Elsevier Mosby.

Ludlow, B.L., 2015. Virtual reality: emerging applications and future directions. Rural Spec. Educ. Q. 34 (3), 3–10.

Luo, H., Li, G., Feng, Q., Yang, Y., Zuo, M., 2021. Virtual reality in K-12 and higher education: a systematic review of the literature from 2000 to 2019. J. Comput. Assist. Learn. 37 (3), 887–901. https://doi.org/10.1111/jcal.12538.

McCallum, J., Ness, V., Price, T., 2011. Exploring nursing students' decision-making skills whilst in a second life clinical simulation laboratory. Nurse Educ. Today 31 (7), 699–704.

Mclellan, H., 1998. Cognitive issues in virtual reality. J. Vis. Lit. 18 (2), 175–199.

Merchant, Z., Goetz, E.T., Cifuentes, L., Keeney-Kennicutt, W., Davis, T.J., 2014. Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: a meta-analysis. Comput. Educ. 70, 29–40.

Nibbelink, C.W., Brewer, B.B., 2018. Decision-making in nursing practice: an integrative literature review. J. Clin. Nurs. 27 (5–6), 917–928.

Padilha, J.M., Machado, P.P., Ribeiro, A., Ramos, J., Costa, P., 2019. Clinical virtual simulation in nursing education: randomized controlled trial [Article]. J. Med. Internet Res. 21 (3), e11529 https://doi.org/10.2196/11529.

Pearson, A., Field, J., Jordan, Z., 2009. Appendix 2: critical appraisal tools. In: Evidence-based clinical practice in nursing and health care. Blackwell Publishing Ltd., Oxford, pp. 177–182.

Peddle, M., 2015. Virtual simulation developing non-technical skills in student nurses and midwives [Article]. Aust. Nurs. Mwifery J. 23 (1), 41. https://www.scopus.com/inward/record.uri?eid=2-s2.0-84942616112&partnerID=40&md5=afd50d9efb443296b51df3a32e62ac79.

Peddle, M., Bearman, M., Nestel, D., 2016. Virtual patients and nontechnical skills in undergraduate health professional education: an integrative review. Clin. Simul. Nurs. 12 (9), 400–410.

Petit dit Dariel, O.J., Raby, T., Ravaut, F., Rothan-Tondeur, M., 2013. Developing the Serious Games potential in nursing education. Nurse Educ. Today 33 (12), 1569–1575. https://doi.org/10.1016/j.nedt.2012.12.014.

Plotzky, C., Lindwedel, U., Sorber, M., Loessl, B., König, P., Kunze, C., Kugler, C., Meng, M., 2021. Virtual reality simulations in nurse education: a systematic mapping review. Nurse Educ. Today 101, 104868.
Polit, D.F., Beck, C.T., 2017. Nursing Research : Generating and Assessing Evidence for Nursing Practice, Tenth edition. Wolters Kluwer.
Protopsaltis, A., Papagiannakis, G., 2020. Virtual reality: a model for understanding immersive computing. In: Lee, N. (Ed.), Encyclopedia of Computer Graphics and Games. Springer International Publishing, pp. 1–4. https://doi.org/10.1007/978-3-319-08234-9_165-1.
Razavi, T., 2001. Self-report Measures: An Overview of Concerns and Limitations of Questionnaire Use in Occupational Stress Research.
Saab, M.M., Hegarty, J., Murphy, D., Landers, M., 2021. Incorporating virtual reality in nurse education: a qualitative study of nursing students' perspectives. Nurse Educ. Today 105. https://doi.org/10.1016/j.nedt.2021.105045, 105045-105045.
Shin, H., Rim, D., Kim, H., Park, S., Shon, S., 2019. Educational characteristics of virtual simulation in nursing: an integrative review. Clin. Simul. Nurs. 37, 18–28.
Slater, M., 2018. Immersion and the illusion of presence in virtual reality. Br. J. Psychol. 109 (3), 431.
Standing, M., 2010. EBOOK: Clinical Judgement and Decision-Making in Nursing and Inter-professional Healthcare. McGraw-Hill Education, UK.
Standing, M., 2020. Clinical judgement and decision making in nursing. Sage.
Taçgın, Z., 2020. The perceived effectiveness regarding immersive virtual reality learning environments changes by the prior knowledge of learners. Educ. Inf. Technol. 25 (4), 2791–2809. https://doi.org/10.1007/s10639-019-10088-0.
Thompson, C., Aitken, L., Doran, D., Dowding, D., 2013. An agenda for clinical decision making and judgement in nursing research and education. Int. J. Nurs. Stud. 50 (12), 1720–1726.
Thompson, C., Stapley, S., 2011. Do educational interventions improve nurses' clinical decision making and judgement? A systematic review. Int. J. Nurs. Stud. 48 (7), 881–893.
Thompson, D.S., Thompson, A.P., McConnell, K., 2020. Nursing students' engagement and experiences with virtual reality in an undergraduate bioscience course. Int. J. Nurs. Educ. Scholarsh. 17 (1) https://doi.org/10.1515/ijnes-2019-0081.
Torraco, R.J., 2016. Writing integrative reviews of the literature: methods and purposes. Int. J. Adult Vocat. Educ. Technol. 7 (3), 62–70.
Whittemore, R., Knafl, K., 2005. The integrative review: updated methodology. J. Adv. Nurs. 52 (5), 546–553.
Yoon, J., 2004. Development of an Instrument for the Measurement of Critical Thinking Disposition: In Nursing. The Catholic University of Korea, Seoul.
Zulkosky, K.D., White, K.A., Price, A.L., Pretz, J.E., 2016. Effect of simulation role on clinical decision-making accuracy. Clin. Simul. Nurs. 12 (3), 98–106.